The annual variation in the radiant distribution of sporadic meteors*

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Abstract - Meteor data obtained from the Southern Hemisphere confirms that the strengths of the helion, apex and antihelion sources of sporadic meteor activity are in the ratio 2:1:2 when averaged over a whole year. During the year the helion and anti-helion source strengths vary from 0.8 to 4.0 times that of the apex.

INTRODUCTION

In the course of a year-long survey of meteoric activity during 1960-61 data of high quality was obtained with much intrinsic information concerning the distribution of meteors in the region of space traced out by the earth's orbit. The results of the survey have been fully reported by ELLYETT and KEAY (1961, 1963). Using these results KEAY (1963) has confirmed that the density of meteors around the earth's orbit is greater in the second half of the year. This fact, combined with the seasonal effects of the axial tilt of the earth, satisfactorily explains the main features of the observed annual and diurnal variations in meteoric activity.

In this paper the survey results mentioned above have been further analysed to show that although the three recognised ecliptic concentrations of sporadic meteor radiants are always present their relative strengths vary considerably throughout the year.

SPORADIC METEOR RADIANT DISTRIBUTION MODEL

In recent years it has been definitely established that the radiants of sporadic meteors tend to be clustered into three major groupings along the ecliptic. On the basis of observations made between 1930 and 1949 by visual observers organised by the British Astronomical Association, PRENTICE and HAWKINS (1953 and 1957) have shown how the distribution of sporadic meteor radiants in ecliptic latitude is sharply concentrated on the ecliptic itself, while the distribution in ecliptic longitude shows two prominent peaks, one at the apex of the earth's way and one near the anti-helion point. Daylight naturally prevented the visual observation of any peak within about 60 degrees of the sun's position.

A detailed analysis by HAWKINS (1956 a,b) of radar observations of sporadic meteors obtained between 1949 and 1951 confirmed the visual result and disclosed a third radiant grouping located near the helion point. Subsequent triple-station radar measurements by DAVIES and GILL (1960) of the orbits of sporadic meteors, and radar observations by WEISS and SMITH (1960) using equipment similar to that used by HAWKINS, have substantiated the previous findings. All of these workers are in agreement that three major groupings of radiants exist but there is some disagreement as to the relative strengths of the groupings. It is generally agreed that the apex grouping is much less compact than the other two, a result to be expected since the apparent concentration of radiants near the apex is a consequence of the streaming effect brought about by the earth's orbital motion.

In the light of these results it is clear that a radiant distribution model consisting of three discrete independent sources superimposed on a uniform background would represent a simple approximation to the observed meteor radiant distribution. Such an approximation has been used quite effectively by MEEKS and JAMES (1959) in their predictions of the monthly variations in mean echo rate observed in forward scatter communication links. When used with the results of the Christchurch survey, in which very low resolution aerial systems were employed, a discrete-source approximation yields even better concord between the computed and observed echo rates.

In the published results there is agreement that the helion and anti-helion sources are located between 60 and 70 degrees in ecliptic longitude on their respective sides of the apex of the earth's way. The obliquity of the ecliptic (23.45°) is such that 65 degrees in ecliptic longitude is equivalent to 65 degrees in right ascension to within $\pm$ 3 percent, depending on season. It would therefore be legitimate for the purpose of this paper to treat these coordinates as equivalent and assume the helion and anti-helion sources to be located at a fixed hour-angle on either side of the apex position. In order to simplify calculations this difference in hour angle was taken to be exactly four hours in each case; or, in other words, the local mean time of meridian transit of the anti-helion source was taken to be 0200 hours, the apex source 0600 hours and the helion source 1000 hours.

SYNTHESIZED DIURNAL RATE CURVES

The aerial system employed during the survey was omni-directional in azimuth and its vertical radiation pattern was known. This enabled the equipment response to be determined as a simple function of the elevation of a radiant (KEAY, 1963). The diurnal variation in meteor rate can therefore be calculated for any given radiant distribution.

The triple-source radiant distribution model defined in the previous section leads to diurnal rate curves (averaged on a monthly basis) which are very close to those actually observed, provided the relative strengths of the three sources are adjusted for best fit. The contributions from the sources are added to the background level defined by the minimum value of the observed diurnal rate curve. The minimum always occurs close to 1800 hours L.T. at the time of transit of the antapex when all three model sources are below the horizon and therefore not contributing to the echo rate. Typical results are shown in Fig. 1., in which the rates calculated from the model distribution are drawn as histograms and the measured hourly rates (centred on the half-hour) are shown as connected dots. The calculated rates for May and September show close agreement with the measured rates. This was also the case for the months of February, April, June and October.

The histogram for July is the extreme example of the inadequacy of the simple triple-source radiant model to cope with a situation where meteors are incident from a complex of radiants not coincident with any of the three source positions defined for the model. Smaller discrepancies of a similar nature were obtained with the diurnal rates calculated for the months of March and August.

A different situation is exemplified by the histogram for December. Here it is the positions as well as the strengths of the model sources which need adjustment in order to obtain best fit to the measured rate values. The anti-helion source evidently culminates somewhat earlier during December while the apex maximum appears to be delayed by the presence of meteoric activity which the simple model cannot encompass. The curves for November and January show a similar, but smaller degree of source misalignment.

During the year two very pronounced peaks of meteoric activity occur, one at the end of July and the other in December (ELLYETT and KEAY, 1963), and it was for these two months that the synthesized rate curves (histograms) were the worst approximations to the observed diurnal curves. Even so the values obtained for the source strengths at these times would never be more than 30 percent in error except for a possible underestimate of 40 percent for the anti-helion source in July and August (see Fig. 2) if the intense meteor showers then present are included in the anti-helion source contribution.

ANNUAL VARIATION OF SOURCE STRENGTHS

The source strengths which yield best fit between the synthesized rates and those actually observed vary greatly during the year. The mean source strengths for each calendar month are plotted in arbitrary units in Fig. 2 and the amounts by which the source strengths can be varied while still maintaining a reasonably good fit are indicated by the upper and lower limits.

The variation in strength of the apex source follows the same pattern as the already established annual variation in the number of sporadic meteors encountered by the earth (KEAY, 1963), but, having a maximum to minimum strength ratio of four to one, it is twice as accentuated. This is readily explained when it is remembered that measurements of the annual variation of sporadic meteor influx includes the helion and anti-helion contributions as well as those associated with the apex.

The variation in strength of the anti-helion source follows a fairly similar pattern, in marked contrast to that of the helion source which stays remarkably constant in strength throughout the year. As a result the anti-helion source is predominant during the latter months of the year while the helion source predominates from March until June.

This helps to explain the observed variations in the time of the daily maximum in the sporadic meteor rate throughout the year. The Jodrell Bank radar results quoted by LOVELL (1957) exhibited a daily maximum which occurred between 0330 and 0800 hours L.T., as shown by the middle plot in Fig. 3. The Christchurch results, on the other hand, usually exhibited two distinct peaks; one before, and the other after, 0600 hours L.T. Fig. 3 reveals that each set of results follows the same trend. From March to June when the helion source predominates and the anti-helion source is at its weakest the peaks occur later in the morning, and towards the end of the year when the anti-helion source is very strong the peaks are displaced earlier.

RATIOS OF SOURCE STRENGTHS

From Fig. 2 it is clear that the relative contributions from each of the three sources varies considerably throughout the year. The ratios of the source strengths referred to the strength of the apex source are shown on a logarithmic scale in Fig. 4 from which it may be seen that both the helion/apex and anti-helion/apex ratios average close to 2 over a full year. This is in excellent agreement with the northern hemisphere results obtained by DAVIES and

GILL (1960). However the month-by-month agreement with the results of DAVIES and GILL is not at all good, possibly because of the fact that their equipment was operated for only 24 hours in each month.

In both northern and southern hemisphere results the anti-helion source varies more than the other two throughout the year although the maximum values occur six months apart in the two sets of results. This disagreement must be due to an observational effect not being properly allowed for in one or possibly both sets of results. Since a fairly low proportion of the meteors observed by DAVIES and GILL were identified as shower meteors it seems surprising that they recorded their highest rates during May, June and July when, according to data from both hemispheres (KEAY, 1963), the relative number of meteors encountered by the earth is low. Nor may their result be explained as an effect due to the axial tilt of the earth which leads to maximum rates during September in the northern hemisphere.

FURTHER WORK

The foregoing remarks show that while the main features of the radiant distribution of sporadic meteors are clear there remains some disagreement concerning the annual variation in the distribution. Since this is of considerable astronomical interest it would be worthwhile to clarify the situation by examining other suitable meteor data such as that accumulated during the operation of communications links utilising meteor forward scatter propogation. Had MEEKS and JAMES attempted to obtain best fit between their calculated rates and those measured over the various communication paths considered they would have obtained the annual variation in each of the three model sources. Alternatively it is possible that other sufficiently consistent meteor data exists which could be analysed to yield the annual source variations.

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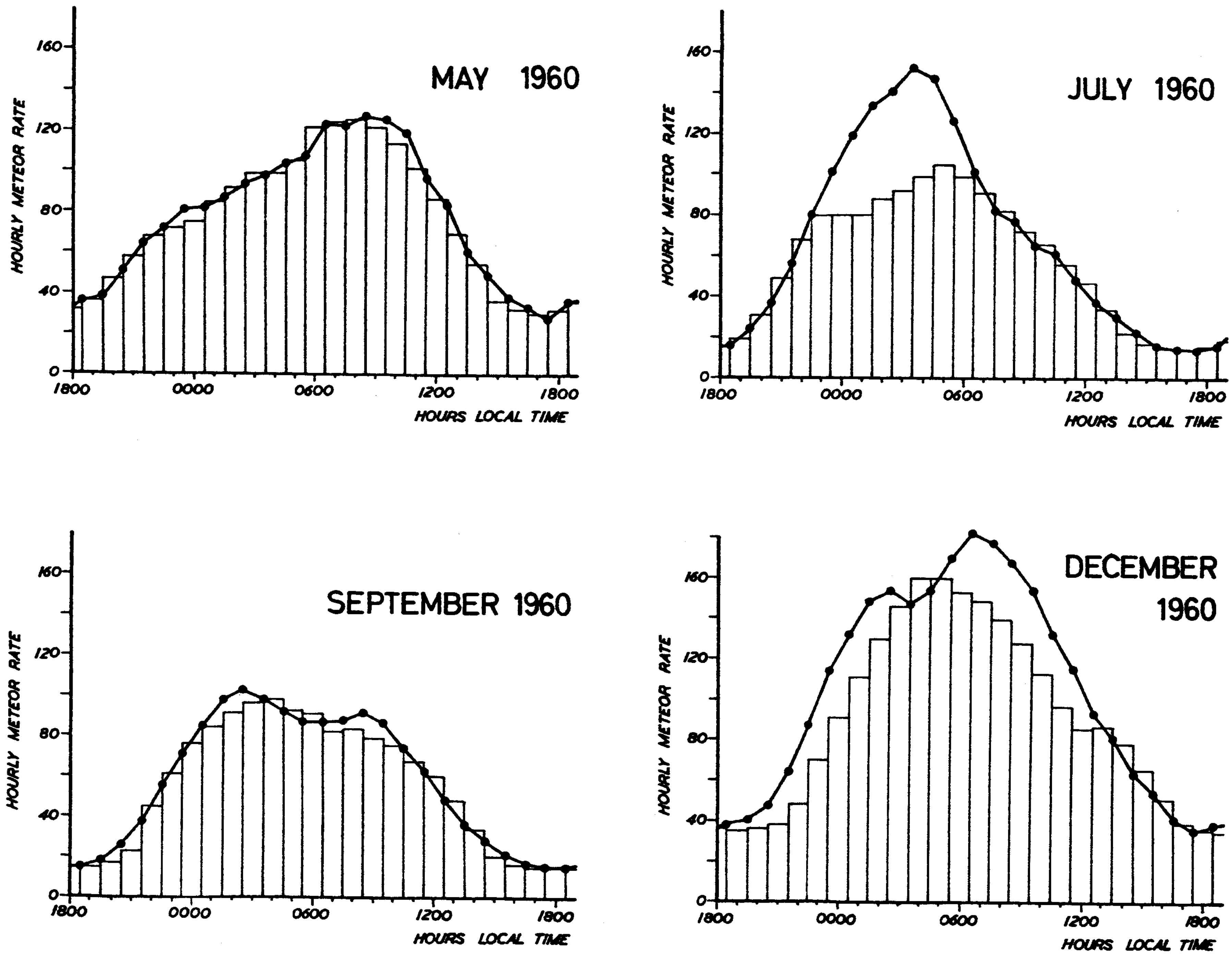

Fig. 1 For each of four selected months the observed diurnal variation in meteor rate is shown by a series of connected dots. The accompanying histograms represent synthesized rates obtained by adjusting for best fit the strengths of each of the three sources in a simple model representing the actual distribution of sporadic meteor radiants.

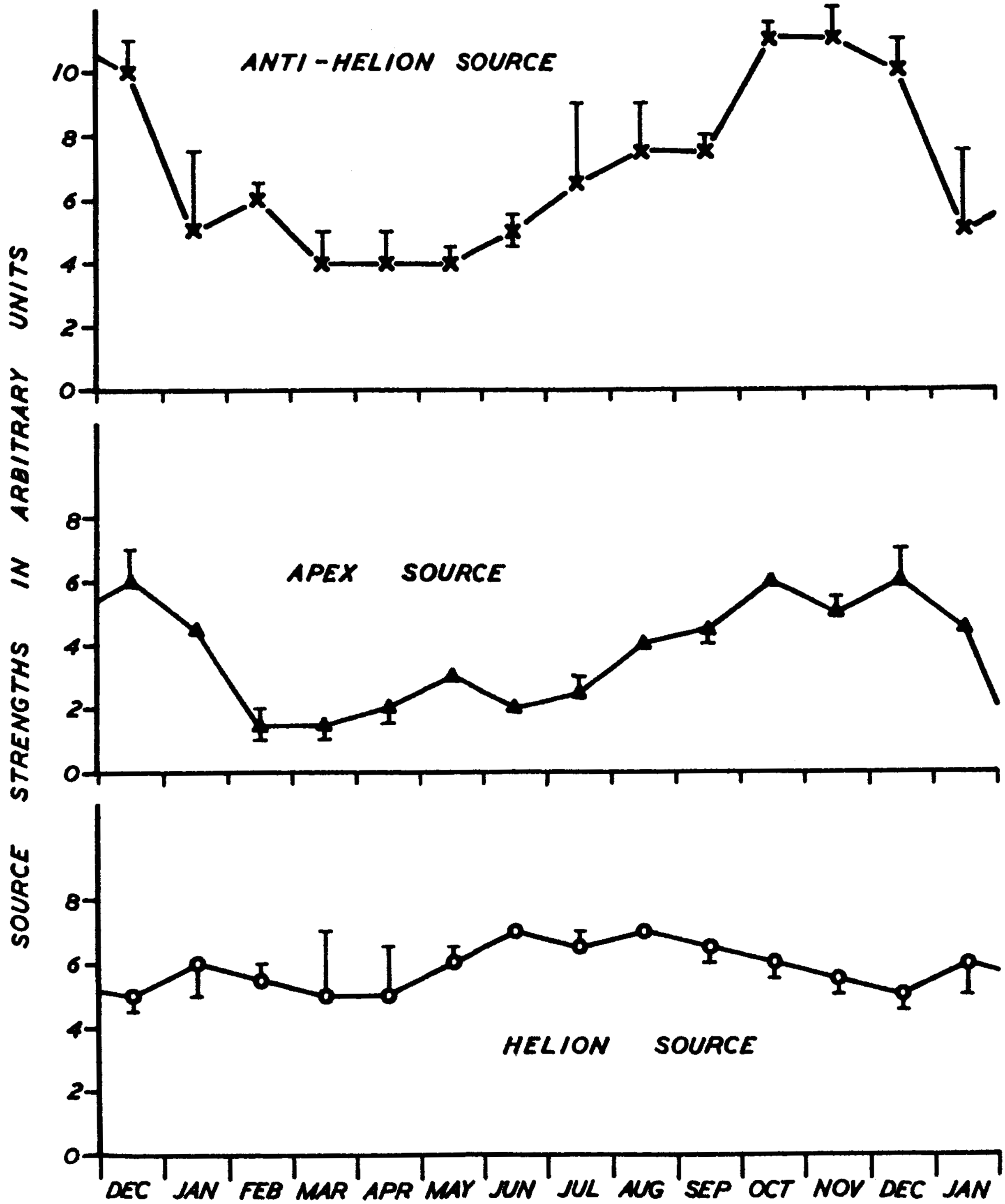

Fig. 2 The calculated annual variation in strength of each of the three major groupings of sporadic meteor radiants along the ecliptic.

Fig. 3 The observed variations in the time of the daily maximum in the sporadic meteor rate throughout the year. The single maximum observed with the Jodrell Bank equipment is shown by the squares, while the circles show the two maxima usually observed with the Christchurch equipment.

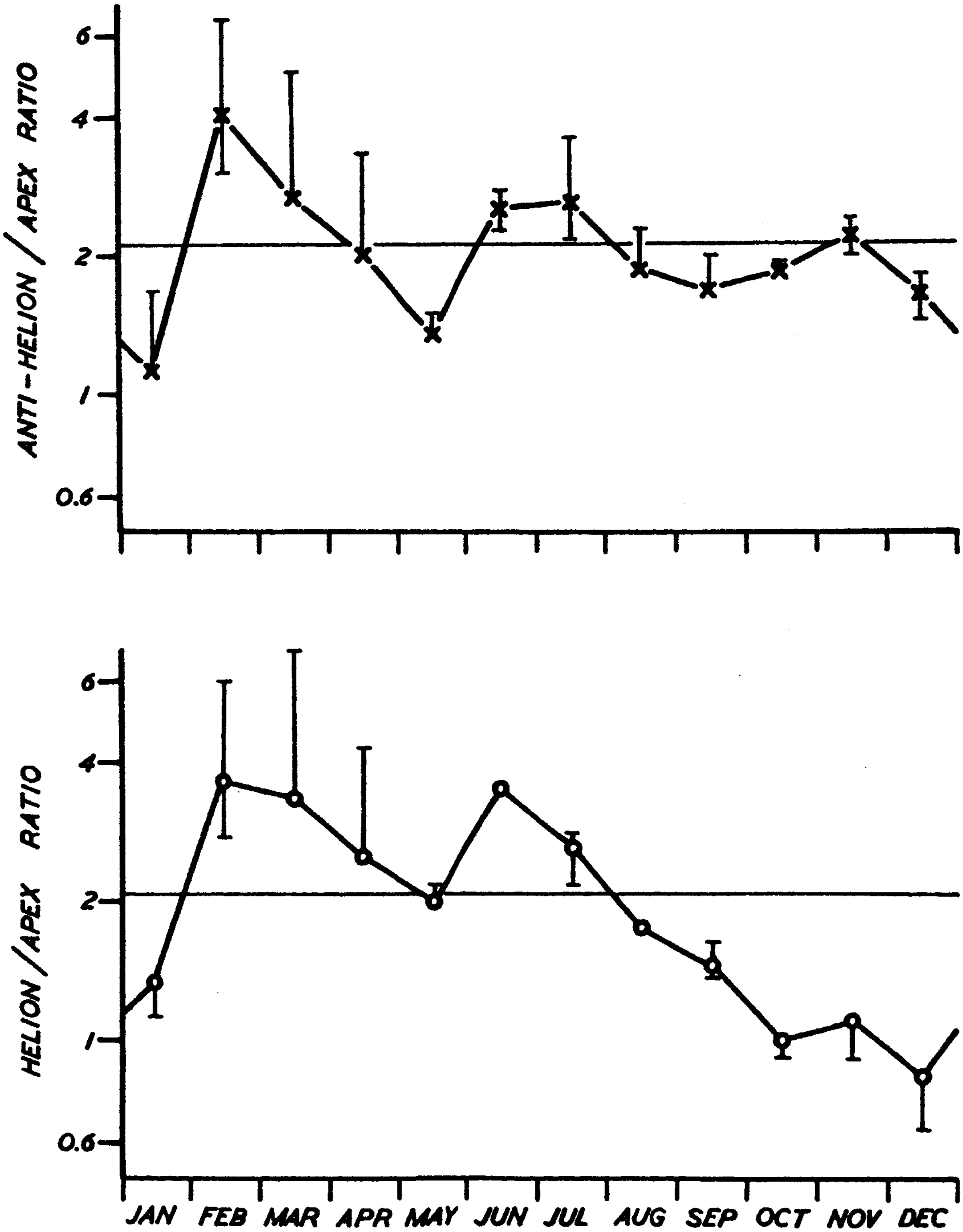

Fig. 4 The annual variation in the ratios of the source strengths.